S. Stone
HEPAP
08/05/02

HIGH ENERGY PHYSICS AT SYRACUSE UNIVERSITY

(see http://www.phy.syr.edu/research/)

Introduction

- Investigations of fundamental properties of our world in terms of symmetries, fields & particles
- Experiment – 2 groups MEP *(DOE funding)* & HEP *(NSF)*
- Theory *(mostly DOE funding)*
  - In order to understand physics at the smallest distances, it is necessary to investigate how particles and space-time interact. Thus our theory group is multifaceted with strong ties to to the Gravity and Astroparticle groups
  - Beowulf PC cluster with 100 Pentium processors

Summary of Theory Topics

- Balachandran: "Fuzzy" Physics & Non-Commutative Geometry (with Martin & O'Connor (Dublin), Immitrzi (Perugia), Gupta (Saha)); Spin & Statistics (with Rojas (Brazil))
- Bowick: Cosmology; Baryogenesis (with Wijewardhana & Suranyi (Cincinnati)); Topological defect formation in Cosmological phase transitions, String Cosmology; Cosmological phase transitions & particle production in field theory
- Catterall: Lattice Supersymmetry; Improved staggered quarks; Non-commutative lattice field theory (with Ambjorn (Neils Bohr)); Simpicial gravity coupled to massless fields
- Schechter: Low energy scalar sector of QCD (with Black (Jefferson lab) & Harada (Seoul)); other aspects of non-perturbative QCD; neutrino physics
- Trodden: Baryogenesis - particularly low-energy mechanisms with direct collider signatures (with Krauss (CWRU), Copeland (Sussex), Lyth (Lancaster)); compact hyperbolic extra dimensions and the unique signatures of their Kaluza-Klein states (with March-Russell (CERN), Kaloper (Stanford) & Starkman (CWRU))
- Wali: Non-commutative geometry; extended objects (with Joshi & Cornell (Melbourne)); clash of symmetries on the brane (with Davidson (Ben Gurion) & Volkas (Melbourne)

Experimental Facilities

Physics Dept. Machine Shop

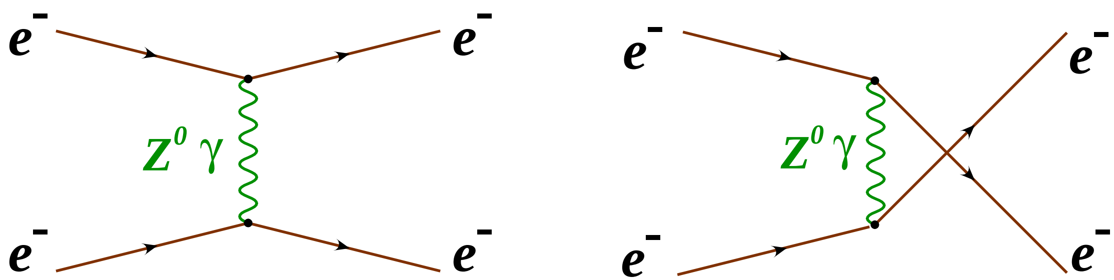
- List of Machines

•**Thermwood 3-axis CNC milling machine with 5' x 10' bed (accurate to ±0.002")**
•Bridgeport J-Head Milling Machines (3) with digital readout
•Rockwell/Delta Drill Press
•HLV 2400 High Precision Toolroom Lathe with digital readout
•Hardinge Production Lathe
•Clausing 15" Lathe
•Le Blonde Gap Bed Lathe
•Do ALL Contourmatic Bandsaw
•Milwaukee Model H Horizontal Milling Machine
•Fosdick Sensitive Radial Drilling Machine
•K. O. Lee Tool Grinder
•Norton Surface Grinder
•Cabinet Bead Blaster
•Hobart Cyberwave Welder with Heliarc accessories and Aircrafter Parts Rotator

MEP Group

- Under leadership of P. Souder
- Past work
  - HAPPEX (JLAB experiment E91-010): Parity violation in elastic scattering from the proton. Final results were recently published in Physics Letters.
  - SLAC experiment E-154: Precision measurement of the neutron spin structure function using a polarized He^3 target
  - SLAC experiment E-142: Measurement of the neutron spin dependent structure function
- Current experiments
  - Several at Jefferson Lab
  - Parity violation in Moller Scattering at SLAC (E158)

Parity Violation in Moller Scattering



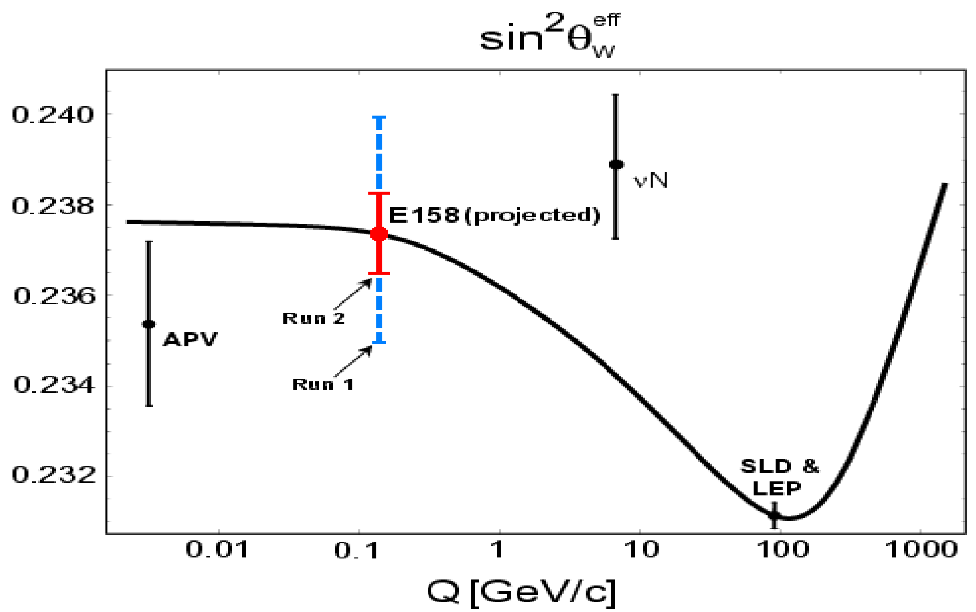
For a polarized electron beam and an unpolarized electron target:

$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$

$$A_{LR} \propto (1 - 4\sin^2\theta_W)$$

$$A_{LR}^{meas} = P_e \cdot A_{LR}$$

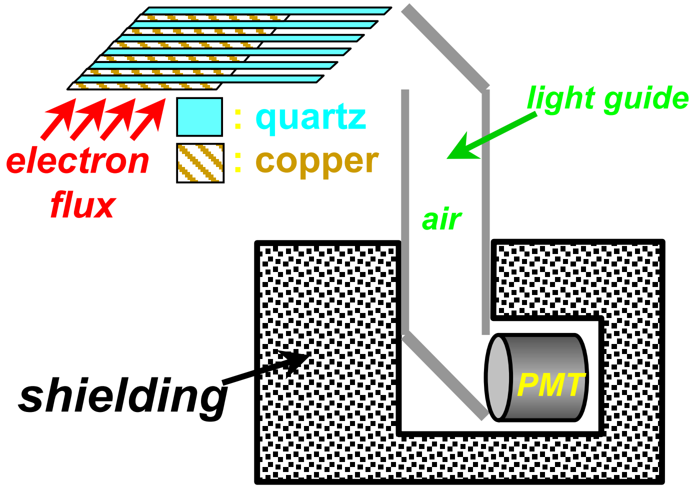
For E158, At tree level, $A_{LR} = 3 \times 10^{-7}$



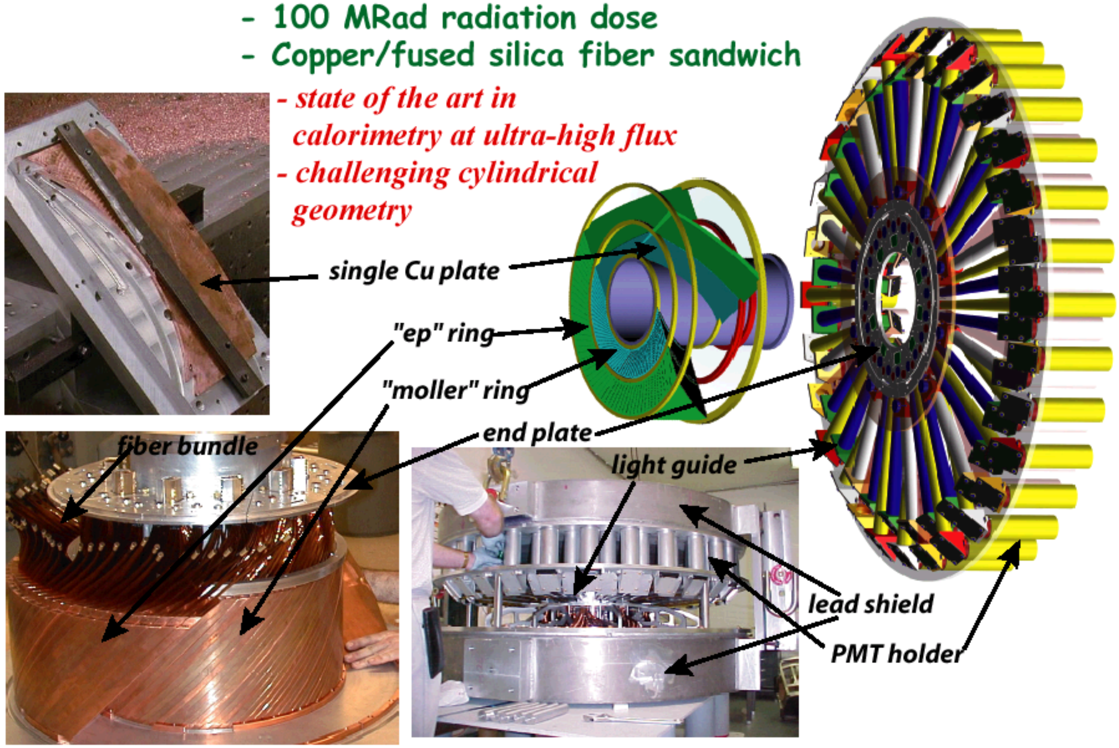
Moller e⁻ Calorimeter

Constructed at Syracuse

Basic Idea:



- 20 million electrons/pulse at 120 Hz
- 100 MRad radiation dose
- Copper/fused silica fiber sandwich
  - *state of the art in calorimetry at ultra-high flux*
  - *challenging cylindrical geometry*



The Experimental HEP Group

Faculty

M. Artuso(1),
S. Blusk(2),
T. Skwarnicki(3),
S. Stone(4), J. C. Wang(5)

Postdocs

B. Dambasuren(6),
R. Mountain(7),
R. Nandakumar(8)

Graduate Students

C. Boulahouache(9),
K. Bukin(10), J. Butt(11),
O. Dorjkhaidav(12),
N. Menaa(13),
L. Redjimi(14), R. Sia(15),
H. Zhang(16)

Undergraduates

B. Gantz(17),
M. Barnes(REU)

Our Facilities

- Computing: PC's on desktops, 9 Alpha Unix boxes with 1 TB of disk, 2 Sun stations
- Electronic Shop – Circuit board design & assembly
- Probe Station for pixel work

Educational Activities

- **Graduate Education**
  - We provide extensive training in hardware, software & physics analysis
- **Undergraduate Education**
  - Many individual research projects, see http://www.phy.syr.edu/hep/edu/undergrad-projects.html
  - We also teach courses
    - M. Artuso: Modern electronics including DAQ
    - S. Stone: Advanced Physics Lab

    Also for grad students
- **Outreach Activities**
  - High School Teacher support, workshops & equipment loan
  - Enders Road (public school) science club

One Day at the Science Club

Lesson on angular momentum - gyroscopes

Past Research Activities

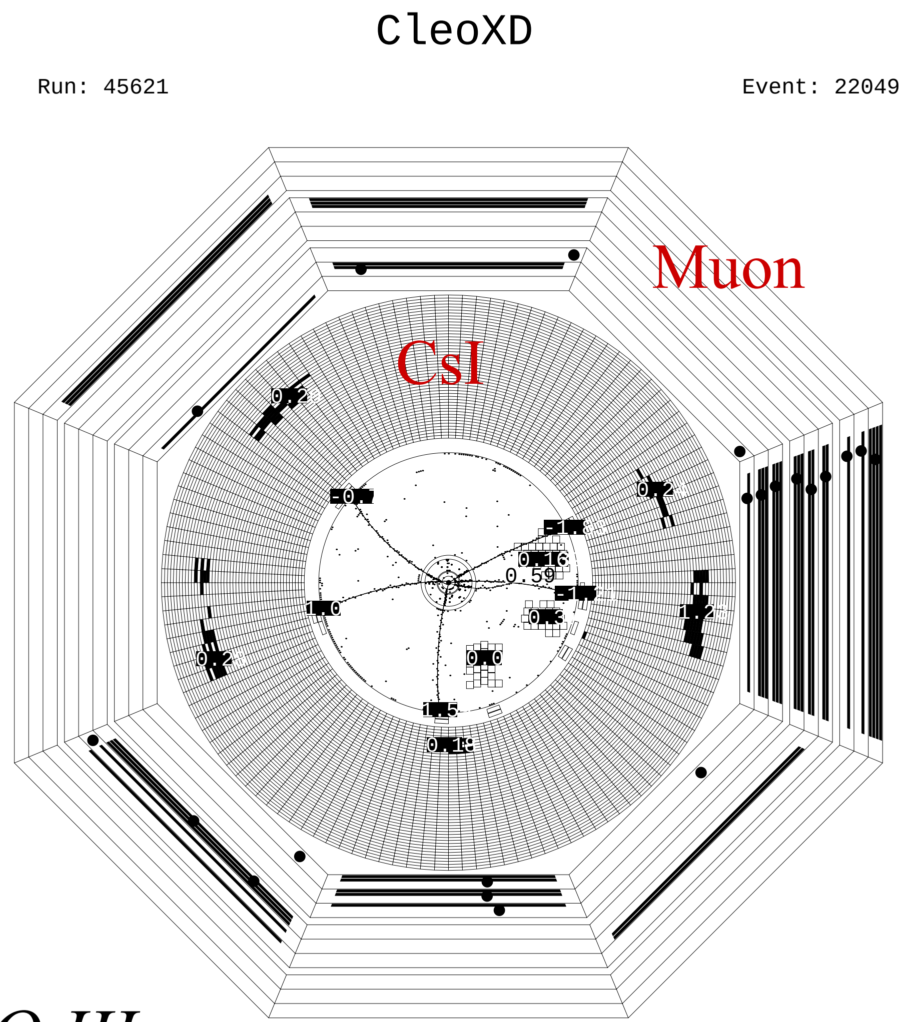
- CLEO Physics Analysis Highlights
  - First observation of Fully Reconstructed B mesons & measurement of the B mass
  - Discovery of the D_s meson at 1970 MeV
  - Measurement of $\mathcal{B}(B \to D^* \ell \nu)$ & first factorization test
  - Best measurement of $\chi(2P)$ masses and transition rates from the $\Upsilon(3S)$
  - First observation of $b \to \Psi X$, $B \to \Psi K$, $B \to \Psi \pi$
  - First measurement of $B \to K^* \gamma$, $b \to s\gamma$
  - First measurement of $\Gamma(D_s^+ \to \mu^+ \nu) / \Gamma(D_s^+ \to \phi \pi^+)$ and f_{D_s}
  - First observation of $B \to \phi K$
  - First observation of the ρ' in B decays & best determination of ρ' mass & width
  - Energy moments in semileptonic B decay, useful for V_{cb}

Graduate Theses in CLEO II Era

- Yoram Rozen: Search for Radiative Decay of B Meson into Strange Meson: $b \to s\gamma$
- Guosheng Zhu: Exclusive B Decays to D* and a Measurement of the B^0-B^- Mass Difference
- Manoj Thulasidas: Hadronic Transitions Between $b\bar{b}$ Quarkonia and Measurement of Inclusive Spectra in B Decays
- Yurii Mukhin: Cabbibo Suppressed and Color Suppressed $B \to J/\psi\ H_d$ Decays as a Possible Probe of CP Violation
- Xing Xia: Search for Electroweak Penguin Decay (Search for $b \to s\ell^+\ell^-$)
- Weipin He: Measurement of Decay Rate of D_s Pure Leptonic Decay and the Pseudoscalar Meson Decay Constant f_{Ds}
- Silvia Schuh: Measurement of the Relative Branching Fraction of Y(4S) to Charged and Neutral B-Mesons
- Erdenbayar Dambasuren: Observation of $B \to \phi K$ Decay Modes
- Chaouki Boulahouache: Lepton Energy Moments, Operator Product Expansion and the CKM Parameter V_{cb} (08/09/2002)

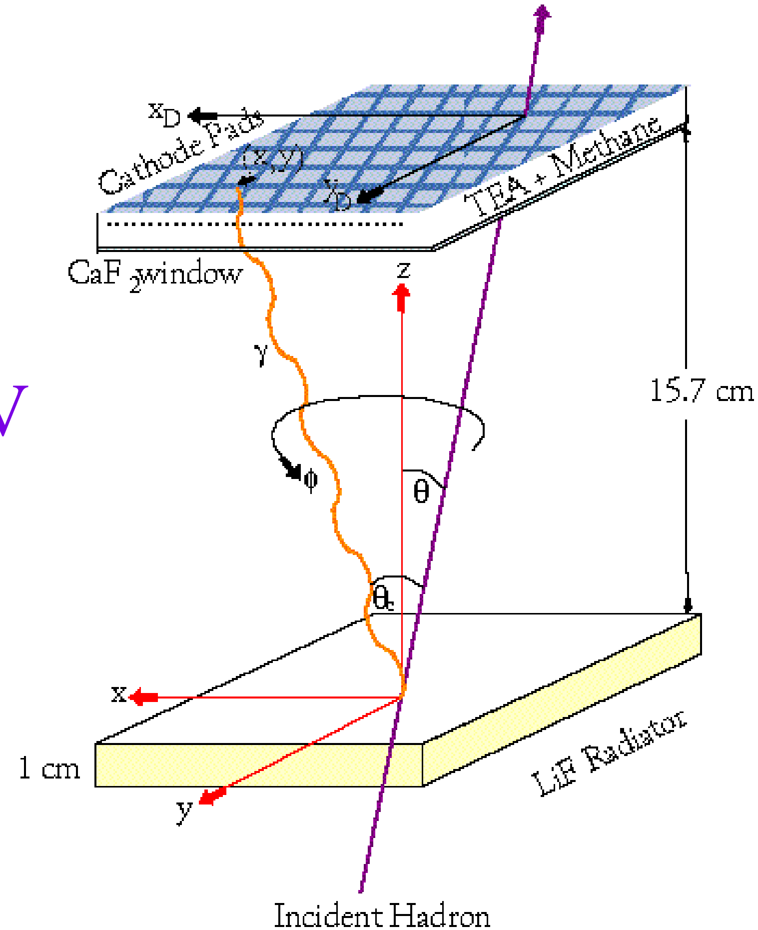
Past Hardware Projects

- *Past activities of current Syracuse faculty*
- CLEO II EM Calorimeter
  - ~8000 CsI(Tl) crystals ~5cm x 5cm inside magnet
  - Copied by Babar & Belle & used as a model by CMS
  - Done by Stone et al while at Cornell, Skwarnicki et al (software), Artuso et al (calibration)
- CLEO II Muon System
  - Skwarnicki et al
- *Both of these are part of CLEO III*

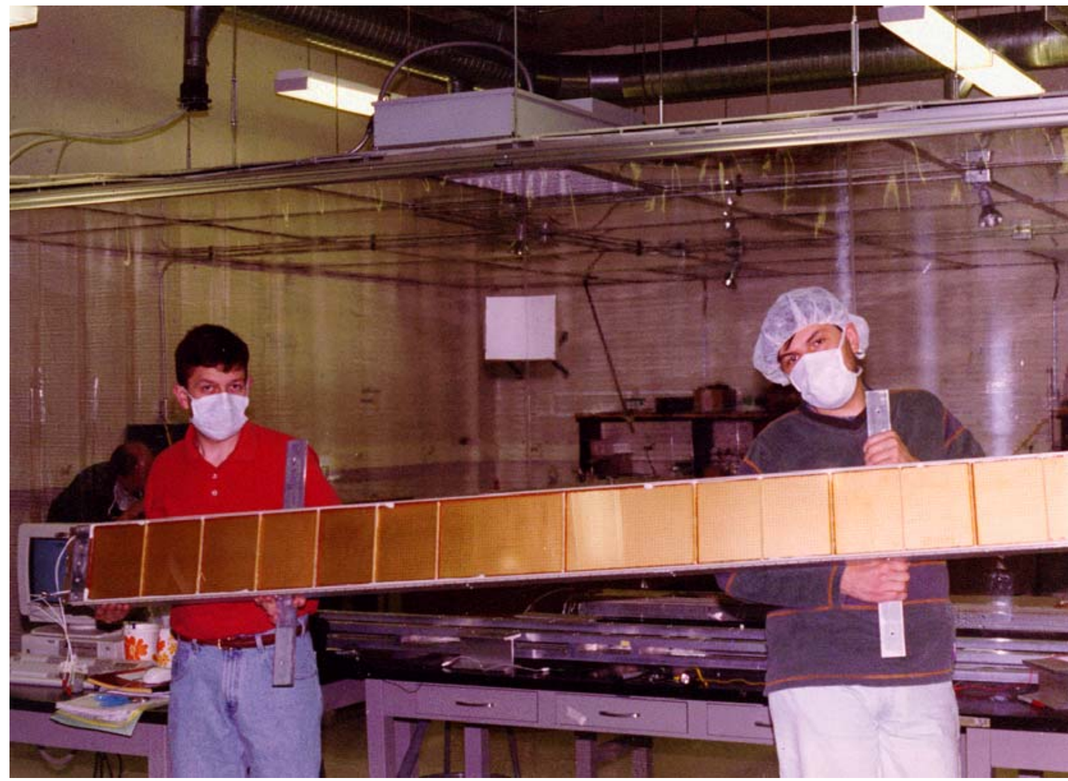


CLEO III RICH Detector

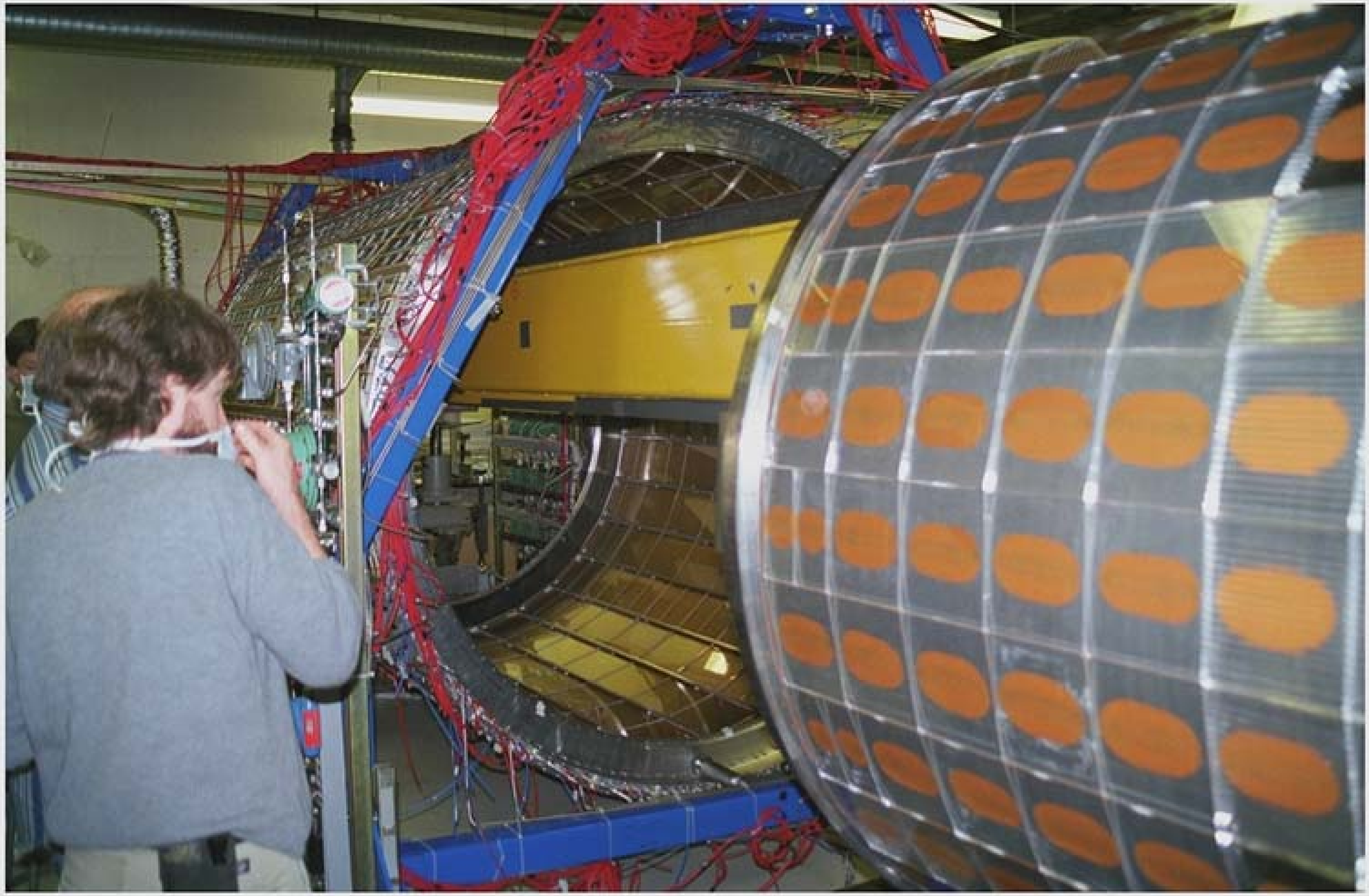
- Syracuse group led the effort.
  - Stone project director, Skwarnicki software, Artuso electronics
  - Lots of help from SMU & Minn.
- Use CH_4-TEA gas to detect single photons. Sensitive in VUV 135-165 nm
- Use LiF radiators
- Use N_2 volume 15.7 cm thick to allow for Cherenkov cone to expand
- Use MWPC with pad readout to measure γ positions



One Cherenkov γ Detector

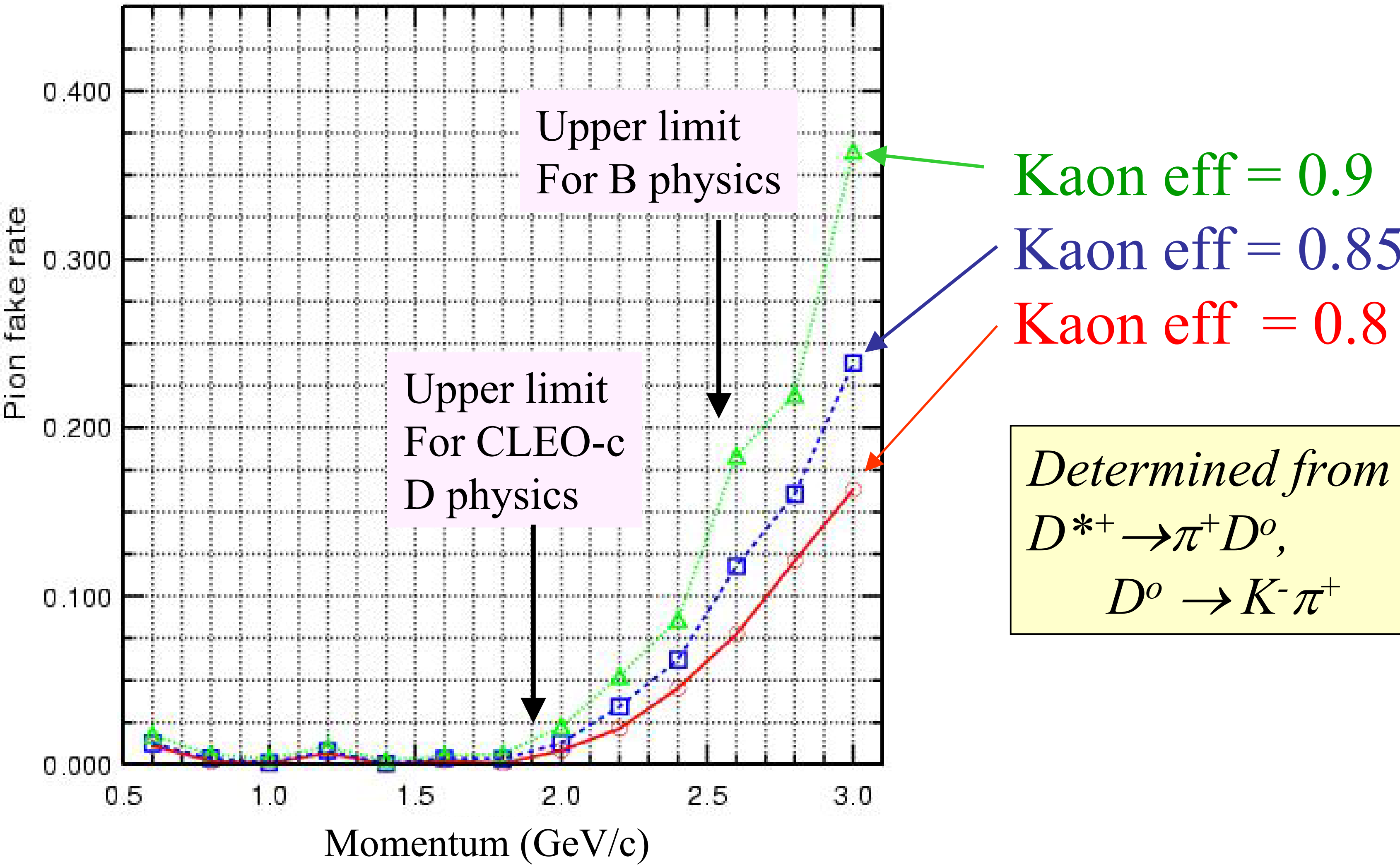


Mating the Radiators to the Photon Detectors



Detector Performance

π fake rate vs. momentum



Determined from
$D^{*+} \to \pi^+ D^o,$
$D^o \to K^- \pi^+$

Advancement of Postdocs

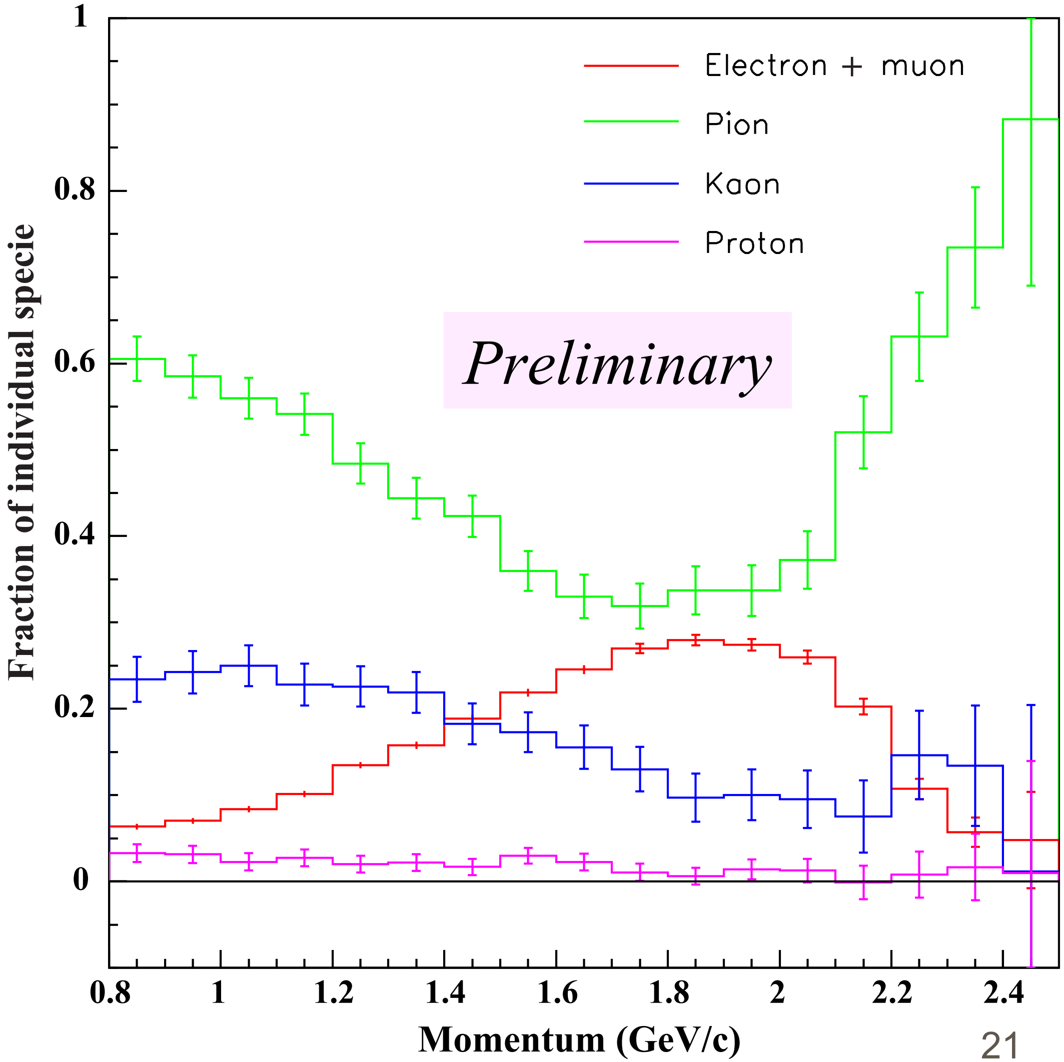
- Rachid Ayad → Prof. at Temple
- Rodney Green → Prof. at Wayne State
- Hassan Jawahery → Prof. at Maryland
- Sacha Kopp → Prof. at Univ. of Texas
- Franz Muheim → Lecturer at Edinburgh
- Stephen Playfer → Reader at Edinburgh
- Philip Rubin → Prof. at William and Mary
- Ian Shipsey → Prof. at Purdue
- Tomasz Skwarnicki → Prof. at Syracuse
- Georg Viehhauser → Advanced Fellow at Oxford
- J. C. Wang → Research Prof. At Syracuse

Current & Future Efforts

- CLEO III Physics Results
- CLEO-c (See Ian Shipsey's talk on Physics Goals)
- BTeV

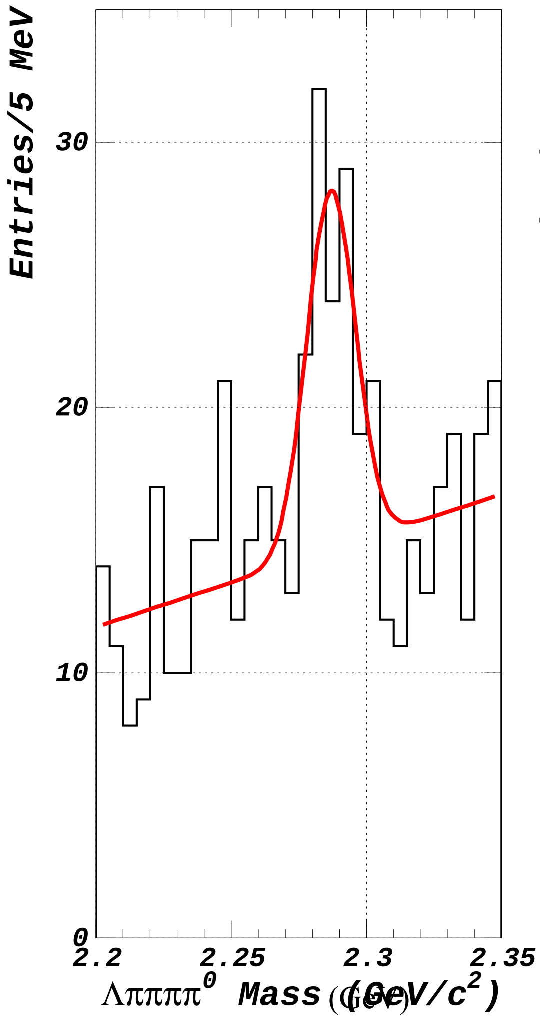
Particle Yields from B Decay

- First measurement of particle fractions
- Use RICH for hadrons above Cherenkov threshold, dE/dx below

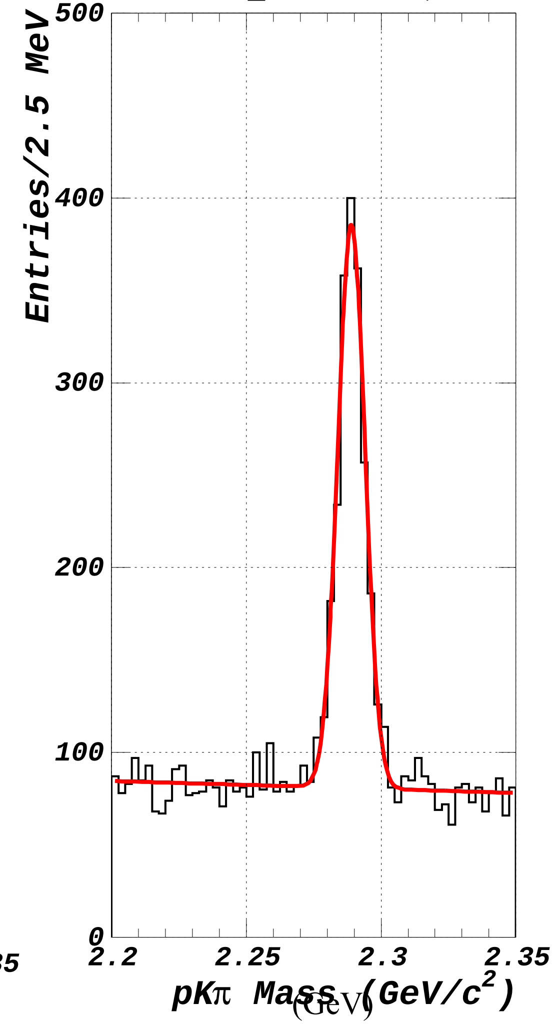


First Sighting of $\Lambda_C \rightarrow \Lambda^0 \pi^+ \pi^- \pi^+ \pi^0$

$m(\Lambda^o \pi^+ \pi^- \pi^+ \pi^o)$

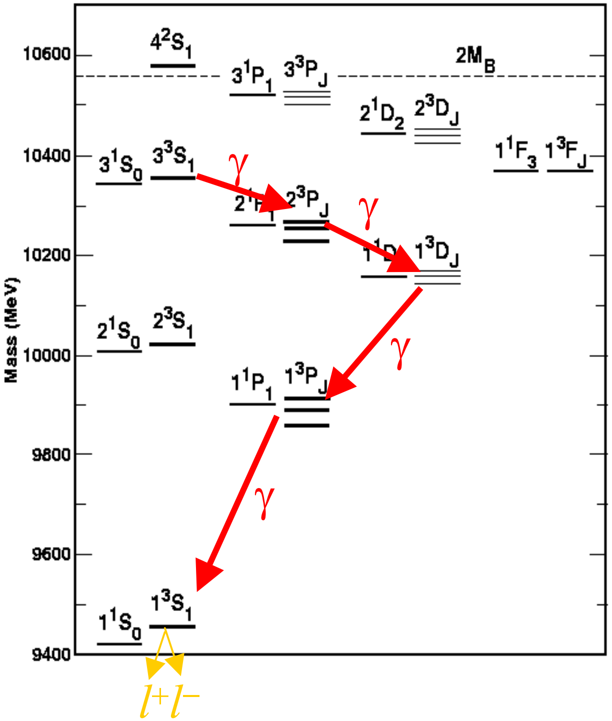


$m(pK^- \pi^+)$

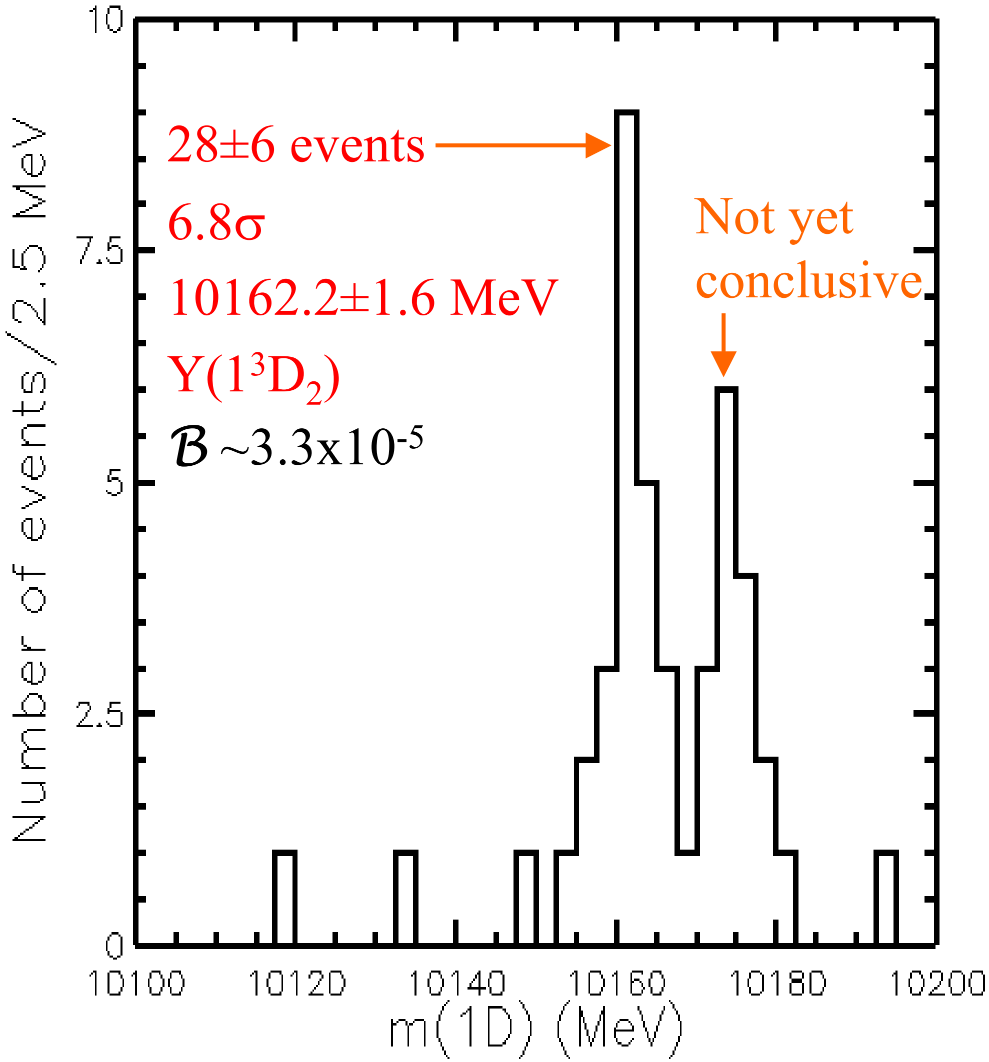


- CLEO III data, x > 3.5
- RICH particle I. D.
- Find 61±13 events after all analysis cuts
- $\dfrac{\Gamma\left(\Lambda_C^+ \rightarrow \Lambda^o \pi^+ \pi^+ \pi^- \pi^o\right)}{\Gamma\left(\Lambda_C^+ \rightarrow pK\pi^+\right)} \sim 0.5$
- 60% $\Lambda_C \rightarrow \Lambda^o \omega \pi^+$, ρ' ?

Discovery of Υ(1D) States



- Search for 4γ transitions with $\Upsilon(1S)\rightarrow\ell^+\ell^-$
- Remove background from other transitions



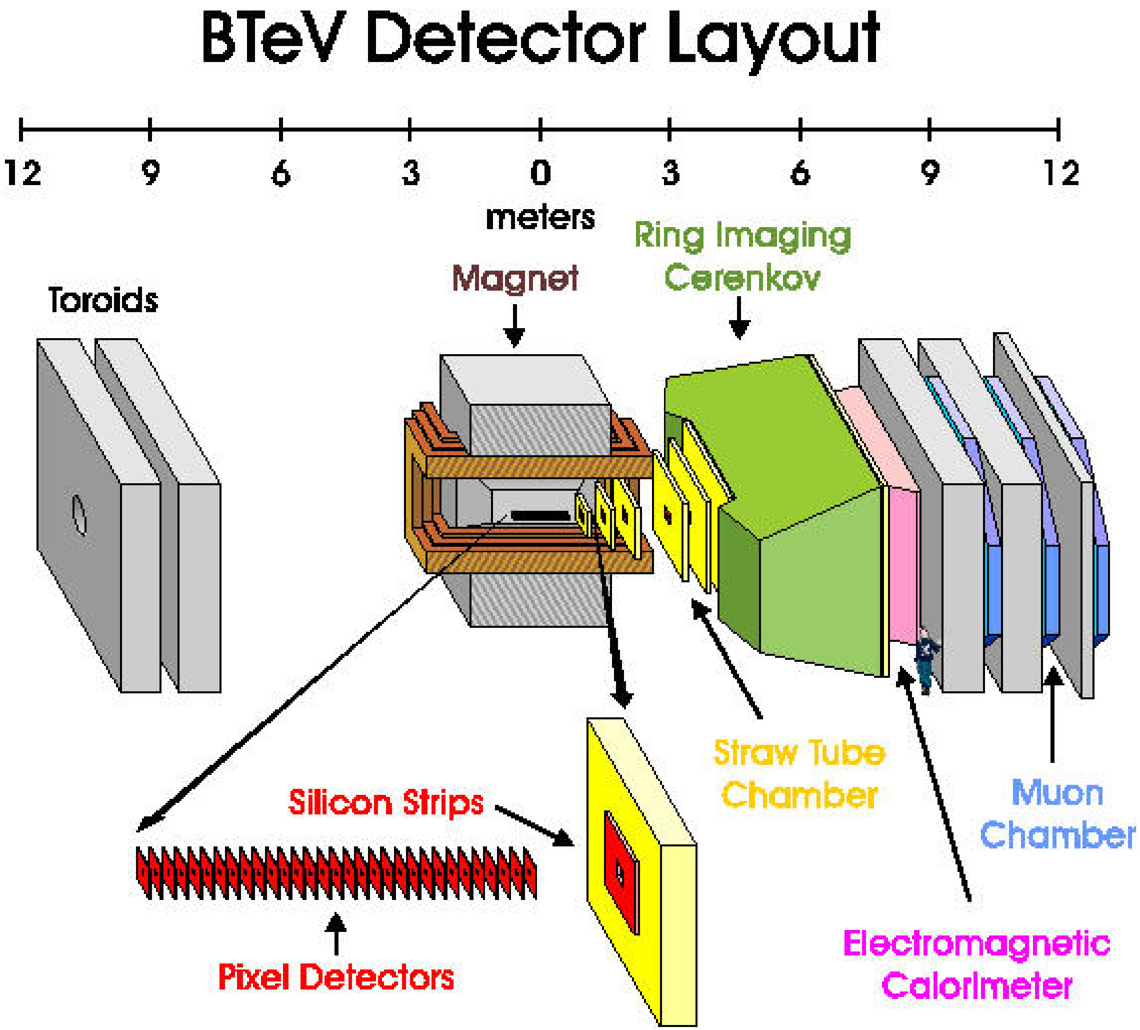
Flavor Physics: some fundamental questions

- Why is there a family structure? Why are there three families?
- What are the quark mixing angles? Can they be fully explained in terms of the SM, or do they arise from new physics?
- Why is there such a striking hierarchy of quark & lepton masses? Are masses tied to the mixing angles?
- Are P and CP the only matter-antimatter symmetries violated in nature, or is CPT violated as well? What physics is responsible?
- What caused baryogenesis in the early universe? Was it a result of CP violation among quarks? Among leptons? What as-yet-unknown particles and interactions were involved?
- What are similarities & differences with ν's, in terms of masses, mixing angles & CP violation?
- *We believe that these are interesting questions that we must answer, in a word "compelling"*

BTeV's Goals

- Our goals are to make an exhaustive search for physics beyond the Standard Model and to precisely measure SM parameters.
- Measurements are necessary on CP violation in B^o and B_s mesons, B_s mixing, rare b decay rates, and mixing, CP violation and rare decays in the charm sector.
- We must thoroughly explore CP violation - *J. Ellis: "My personal interest in CP violation is driven by the search for physics beyond the Standard Model…"*
- Look in rare decays to discover new physics
- Test for inconsistencies in the Standard Model especially in CP phases: If/when found go beyond the SM & elucidate new physics

The BTeV Detector

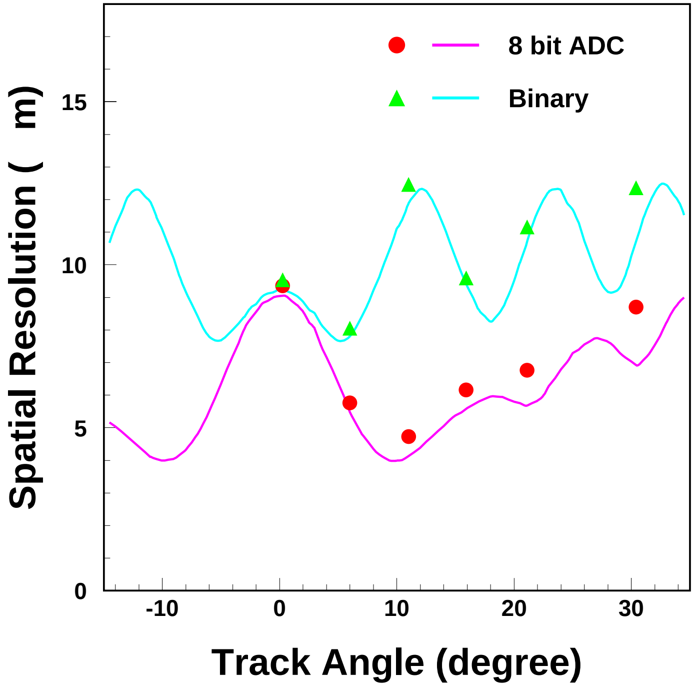


Syracuse Activities

- Co-spokesperson (Stone)
- RICH detector
  - Project co-leaders: Artuso & Skwarnicki
- Pixel detector (Artuso)
- EM calorimeter (Stone)

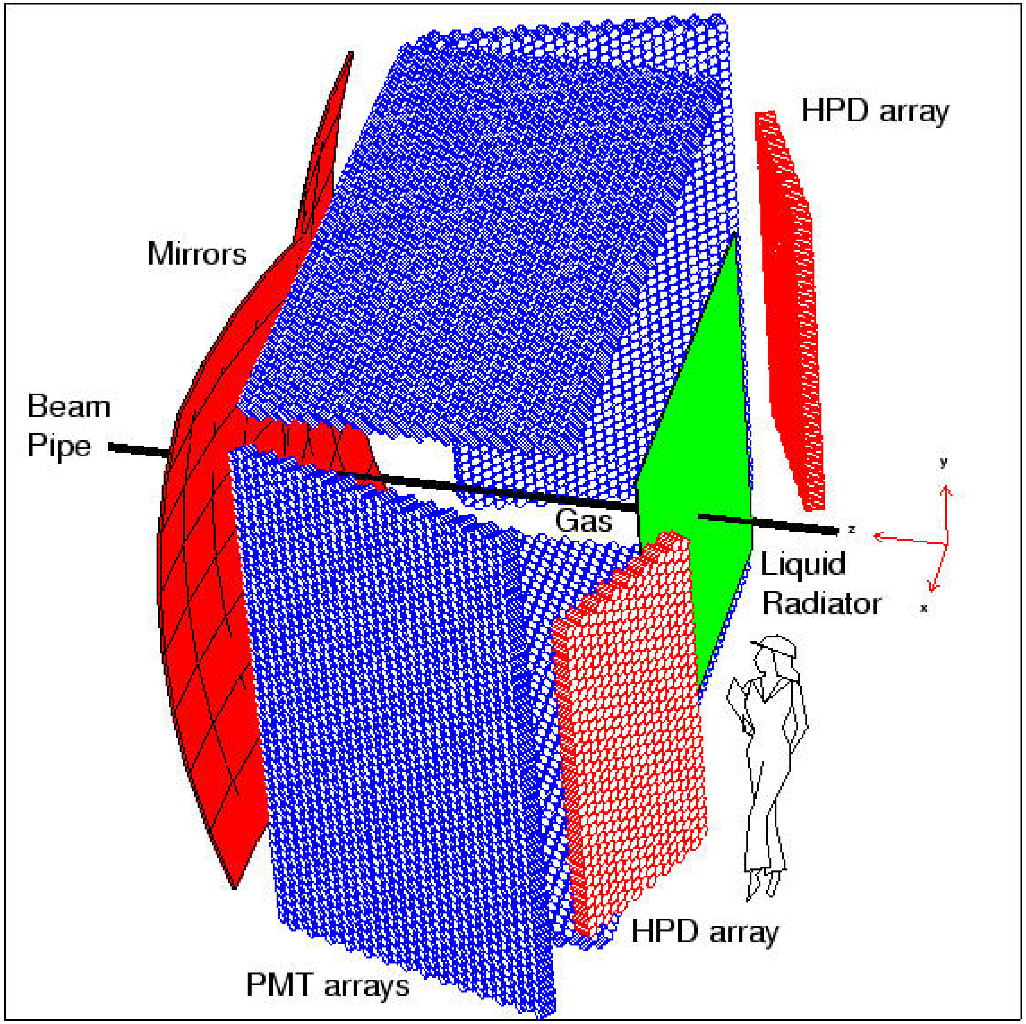
Pixel Detector

- BTeV relies on triggering b & c decays by the presence of a detached vertex. Use of 50 x 400 μm^2 pixels allows a fast vertex determination at the first trigger level, giving ~50% efficiency on b decays and rejects minimum bias background by a factor of 100.
- Syracuse is involved in sensor design (use of probe station), beam tests, simulations,etc…

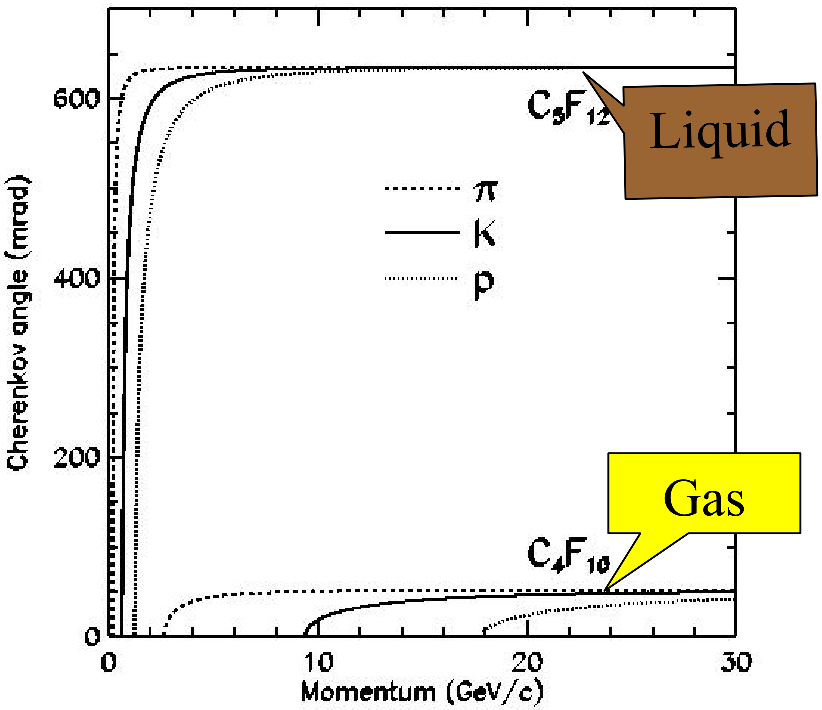


Test Beam results
Compared to simulation

RICH Description



Cherenkov angle vs P

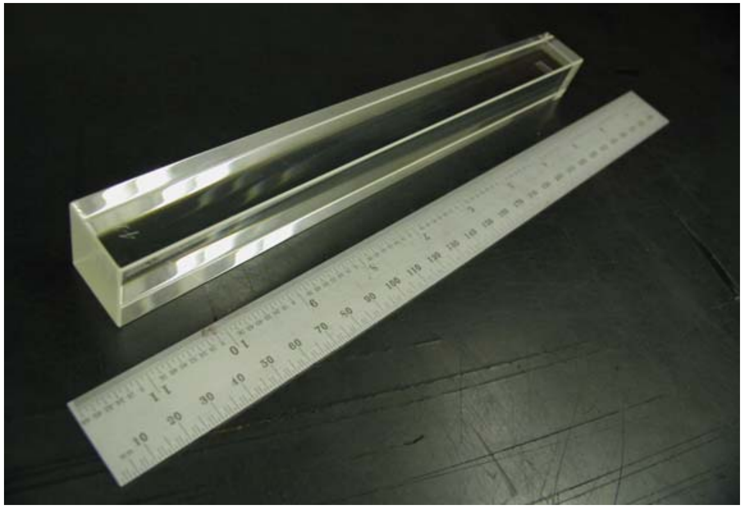


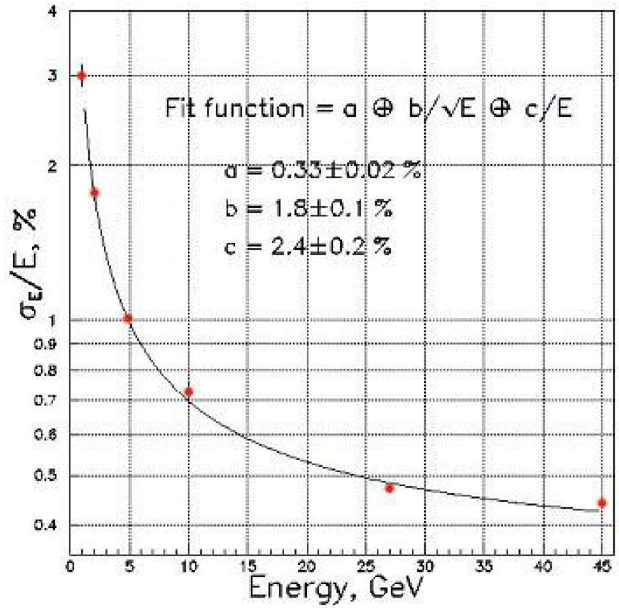
Full separation of π/K/p
From 3-70 GeV/c; sep
e/π <23, μ/π<15 GeV/c

RICH R&D

- Photon detectors
  - Hybrid Photo-Diodes (have a photocathode as in a PM tube but accelerate photoelectrons to 20 kV and smash into pixelated silicon detector. Work on electronic readout, magnetic shielding ….
  - MAPMT – improved Hamamatsu segmented PM tubes that are being evaluated – may be a better solution
- Electronic readout
- Simulations leading to detailed system design
- Test beam in Spring

Lead Tungstate Electromagnetic Calorimeter

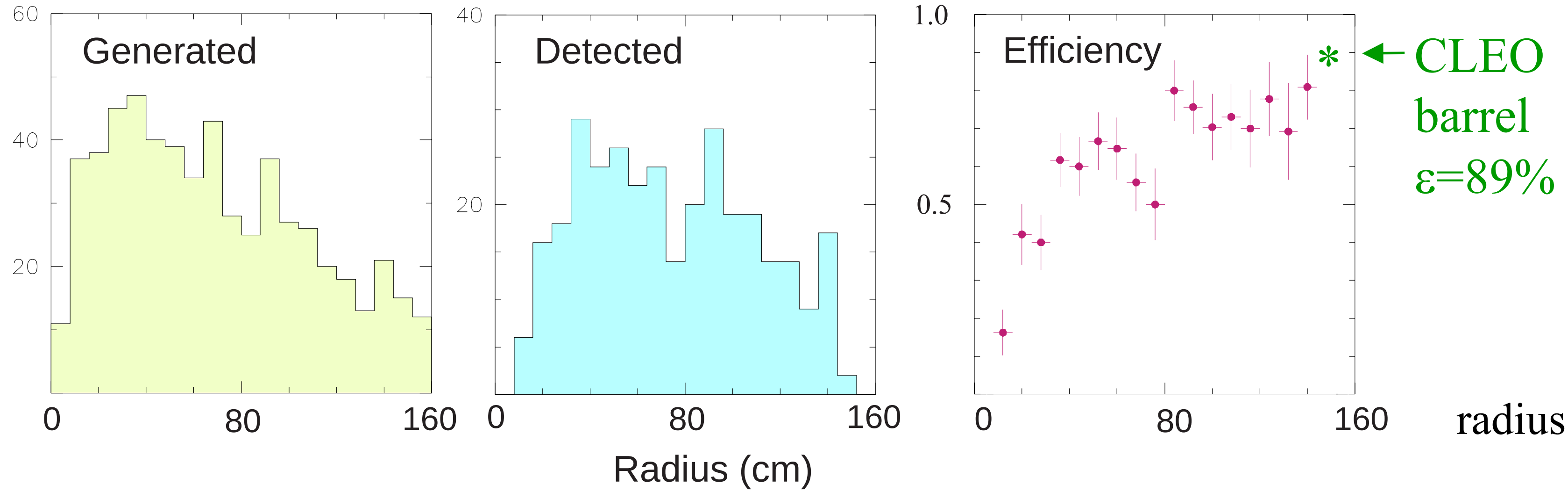


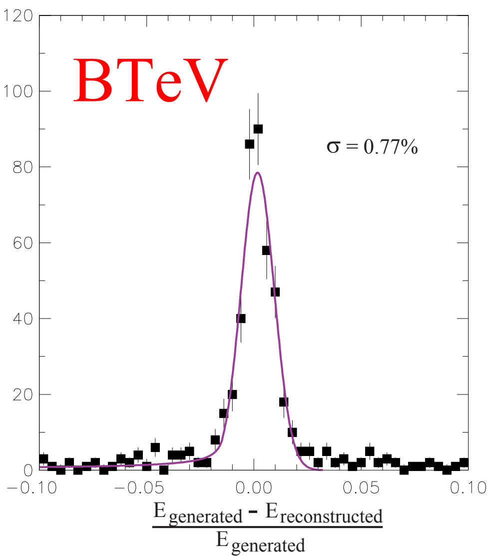


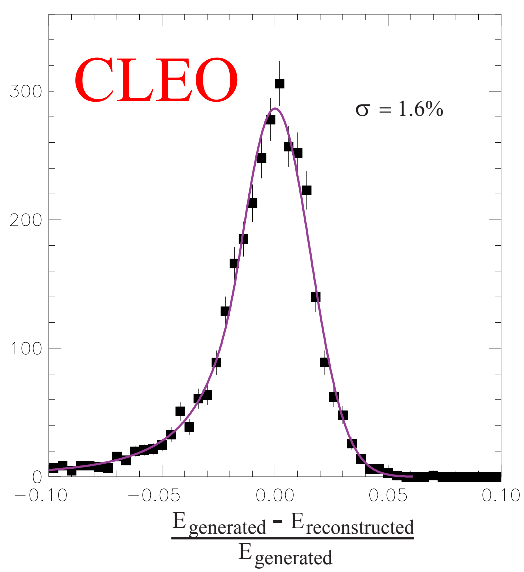
Energy Resolution measured at Protvino by BTeV

Lead Tungstate Crystals similar to CMS. Capable of excellent energy and spatial resolution. We will read them out with PHOTOMULTIPLIER tubes unlike CMS which uses avalanche photodiodes (and triodes for endcap) because of magnetic field.

EM Cal Performance:
Example $B \to K^* \gamma$







- ◆K & π tracks required to pass through RICH
- ◆Isolation & shower shape cuts on both

This system can achieve CLEO/BaBar/BELLE-like performance in a hadron Collider environment!

Physics Reach (CKM) in 10^7 s

Reaction	$\mathcal{B}$(B)(x10^{-6})	# of Events	S/B	Parameter	Error or (Value)
$B^o \rightarrow \pi^+\pi^-$	4.5	14,600	3	Asymmetry	0.030
$B_s \rightarrow D_s K^-$	300	7500	7	γ	8^o
$B^o \rightarrow J/\psi K_S$ $J/\psi \rightarrow \ell^+\ell^-$	445	168,000	10	sin(2β)	0.017
$B_s \rightarrow D_s \pi^-$	3000	59,000	3	x_s	(75)
$B^- \rightarrow D^o (K^+\pi^-) K^-$	0.17	170	1		
$B^- \rightarrow D^o (K^+K^-) K^-$	1.1	1,000	>10	γ	13^o
$B^- \rightarrow K_S \pi^-$	12.1	4,600	1		$<4^o$ +
$B^o \rightarrow K^+\pi^-$	18.8	62,100	20	γ	theory errors
$B^o \rightarrow \rho^+\pi^-$	28	5,400	4.1		
$B^o \rightarrow \rho^o\pi^o$	5	780	0.3	α	$\sim 4^o$
$B_s \rightarrow J/\psi \eta$,	330	2,800	15		
$B_s \rightarrow J/\psi \eta'$ $J/\psi \rightarrow \ell^+\ell^-$	670	9,800	30	sin(2χ)	0.024

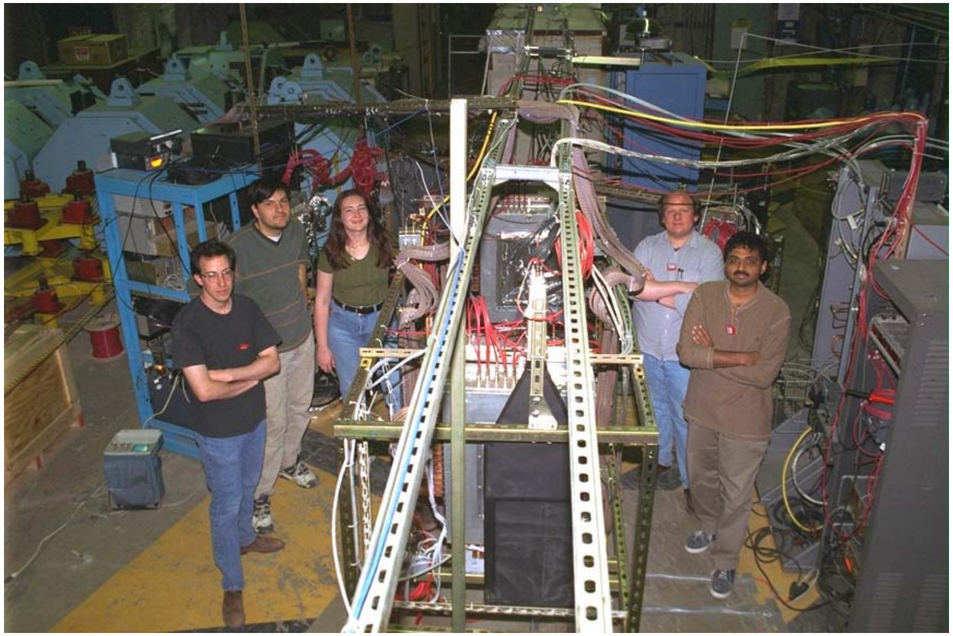
Importance of Training Young Scientists

- The future of High Energy Physics in the U. S. relies on the training of young scientists in American Universities.
  - To fully exploit the University involvement, it is best to do this relatively close by, at least in the same country, so there can be active interaction between students and faculty at all stages of the experiment.
  - BTeV is relatively small so it provides graduate students and postdocs with the opportunity to contribute to and understand the whole experiment, not just one small part. This is the best way to train leaders for the field.

Conclusions

- Great facilities, mix of students, fantastic accomplishments in Theory, Parity Violation (MEP group) and CLEO
- Bright future for all; in Experimental HEP, with CLEO-c

  & BTeV



CLEO III RICH test beam run at FNAL